EVALUATION METHOD TO DETERMINE THE SUCCESS POTENTIAL AND THE DEGREE OF INNOVATION OF TECHNICAL PRODUCT IDEAS AND PRODUCTS

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Abstract

Innovative products are the key to success for all kinds of companies, especially in a highly competitive global market. The evaluation of innovative ideas and products with regard to their success potential – in terms of market penetration – and the degree of innovation is a special challenge for research and development departments as well as for management. Therefore a new evaluation method was developed to quantitatively determine these two characteristic values. The basis of the new method is Quality Function Deployment, which was modified and expanded to consider aspects of novelty and enhanced customer and manufacturer benefit.

The method was evaluated in five pilot projects of well-known companies from different industries. The evaluation shows that the method can be used for evaluating both individual elements of a product development process and entire technical systems and that it makes "innovation" measurable. The calculated evaluation figures are very well suited for decision making in the product development process. In combination with criteria of enterprise-specific planning strategies, decisive indications are made available to management to improve the capability for innovation. All in all the method makes a significant contribution to improving the product development process in terms of quality, time and costs.

Keywords: Evaluation method, degree of innovation, innovation-management, improvement of development process and competitive edge

1 Introduction

The competitiveness of an enterprise is secured by market-driven product innovations rather than by cost reduction programmes [16]. The purpose of these innovations is to develop and to modernise an enterprise [11] and to guarantee a head start on the market [5]. Innovative products are the key to success for all enterprises, especially in a competitive global market [10]. Nowadays, the term "innovation" is used in many fields – ranging from engineering to economics to politics – in different ways and often without knowing the exact meaning.

"Innovation" means renewal (lat.: innovare – to renew). As far as economics is concerned, innovation signifies the introduction of an idea into the market or the conversion of scientific results and new ideas into a market economy-related or technical realisation [2]. Furthermore, the term "innovation" also refers to methodological, financial, administrative, social and ecological novelties [2], [17].

In order to successfully develop innovative products, methods are necessary which are particularly related to the innovative parameters "novelty" and "successful commercialization". The different phases of development of a novelty from the idea up to the readiness for marketing stage represent the so-called "innovation process".

In the last few years, the Center for Product Design (ZPE) of the ETH Zürich developed an "ETH reference model of the innovation process" which also refers to management aspects and, above all, can be put into operation (Figure 1). It is therefore a very comprehensive model which meets the required new, integrative and cooperative understanding of the innovation process [14].

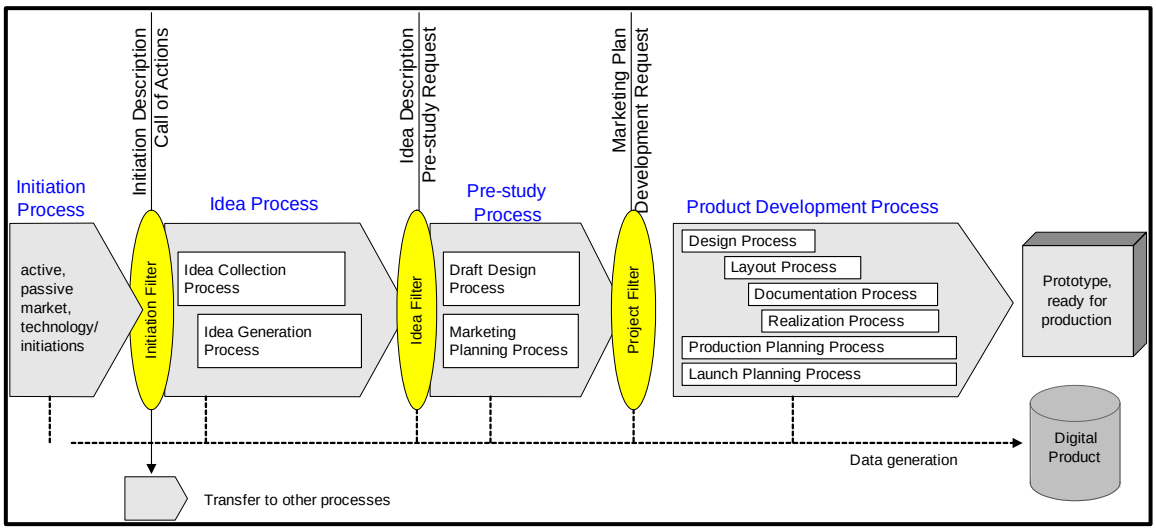

Figure 1. ETH reference model of the innovation process [14]

In order to develop innovative products, new assessment tools and evaluation methods are required. One of the most important tasks during the innovation process is to separate very promising ideas or solutions from those which are less promising (see "filter" in Figure 1) at an early stage. The process of selection of what is perceived to be the "best ideas" or the "best solutions" will have a strong influence on the effectiveness and efficiency of a development department [8], [9].

A search of the literature regarding development processes for new products indicates that there is still no quantitative appraisal and evaluation method which integrates the complex central factors "novelty" as well as "enhanced customer and manufacturer benefit" – and it is these factors which are the crucial final determinants of the success of a product.

In order to launch successful products, a detailed knowledge of customer requirements and their conversion into product requirements is necessary. The most exact possible fulfilment of customer requirements is an essential criterion for quality. For every enterprise, this results in the following basic questions:

- Have all customer wishes been accurately analysed and implemented?
- How innovative is the product?
- What is the ranking of the product on a defined scale in comparison to competitive products?

Based on these questions, a new evaluation method should be applied to identify the chances of market penetration (success potential) and the degree of innovation of technical product ideas and products. The objective of this new evaluation method is the determination of quantitative parameters which will allow a comparison with other products (preceding models or competitive products).

2 State of research

At first, numerous conventional procedures of engineering design, such as selection and evaluation methods, or methods for designing for quality, e. g. FMEA and QFD, were examined with regard to their capability as evaluation and appraisal methods for innovative ideas and products. A search of the literature indicates that conventional methods are not sufficient to evaluate innovative ideas and products according to the objectives of the new method. In most cases, the usual methods of engineering design [14] for evaluating particular sectors of the development process only provide qualitative indications and seldom quantitatively utilisable results [4]. Even if these evaluation methods of design engineering are modified accordingly, it is not possible to quantitatively determine the parameters of innovations, market penetration capability and degree of innovation.

3 Definition of the task

The success of an enterprise is significantly influenced by strategic product planning. In this regard, success factors specific to the product and the industry sector must be analysed and taken into consideration. The successful penetration of a product into the market finally depends on the interaction of factors related to market analysis, business management, science and engineering. Therefore, overall entrepreneurial decisions must be based on criteria such as company strategy, core competencies, market trends and economic and technical aspects, etc.

The described method primarily deals with scientific-technical aspects. Economic efficiency aspects are here only considered to a lesser extent in connection with the manufacturing costs of the product. Therefore, this method can play an important role within an overall entrepreneurial evaluation, primarily from a technical point of view.

4 The key to the solution

Updated definitions of genuine “(product) innovation” imply that a product not only has to be *new*, but also *successful* on the market [14]. A product can certainly be called “successful” if it offers a higher benefit than other products to both the customer and the manufacturer and if it is accepted on the market. The following definition can be derived from this analysis:

A product innovation is the successful realisation of a creative new idea or invention with an enhanced customer and manufacturer benefit.

The following points need to be taken into account:

- In practice, innovation is connected to the existence of a relative advantage, an improvement. This fact is specified as enhanced customer benefit, for example, in comparison to a previous model or a competitive product. In other words, enhanced customer benefit means a better fulfilment of the tasks or to put it in a nutshell: “the product solves problems better” [6], [7], [18].
- The successful realisation is the prerequisite for *enhanced manufacturer benefit*, and, in the end, for the success of the enterprise.
- Furthermore, the bringing to market of a creative idea or an invention known for a long time but not yet implemented can be called innovation as well.

According to this definition, the task of making innovation measurable raises the problem of how to quantitatively determine the degree of novelty and the enhanced customer and manufacturer benefit of an innovation (Figure 2).

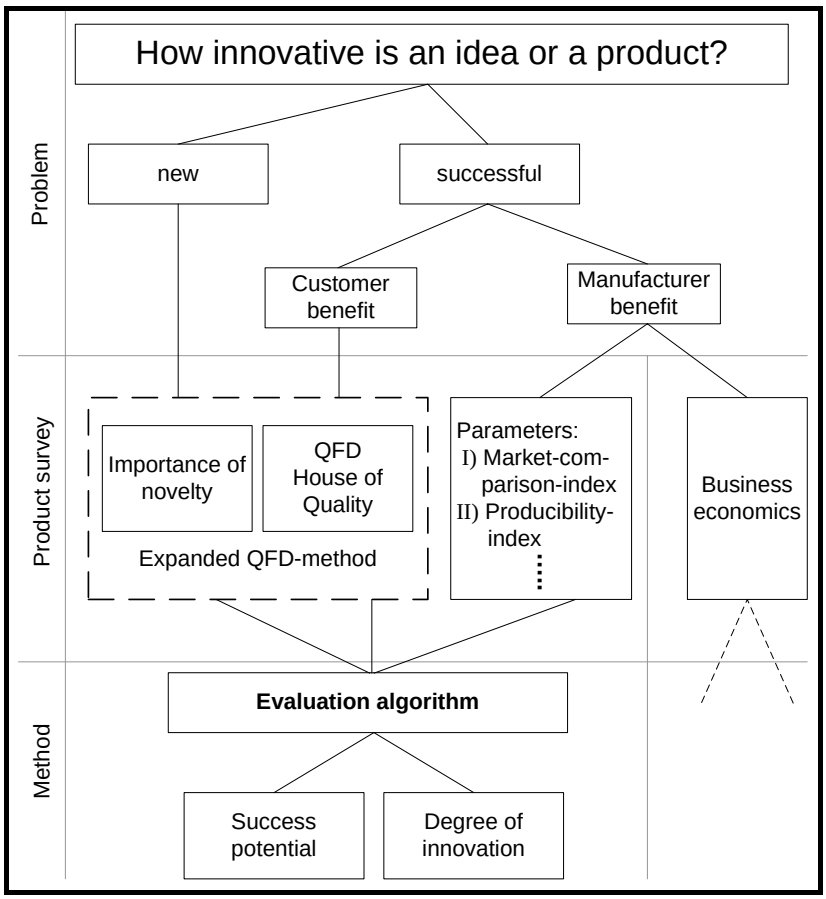

Figure 2. Solution approach for the evaluation of innovative ideas and products

In order to measure the manufacturer benefit, business economics provides many approaches and operating figures, such as turnover, contribution margin, profit, etc. which, therefore, are not taken into consideration in this paper. The new method focuses on the aspects: *innovation* and *customer and manufacturer benefits from a technical point of view*. Since *customer benefit* can be equated with the best possible fulfilment of customer requirements, the new procedure must, as a first step, analyse customer requirements and their conversion into product requirements. To achieve this, the solution approach uses elements of the QFD method.

QFD means “Quality Function Deployment” and can be described as “the planning and development of the quality functions of a product according to the quality characteristics required by the customers”. Cooper [3] calls the QFD method the aggregation of quality and function in a product. The first QFD phase, slightly changed, is very suitable for the technical survey of a product (Figure 3).

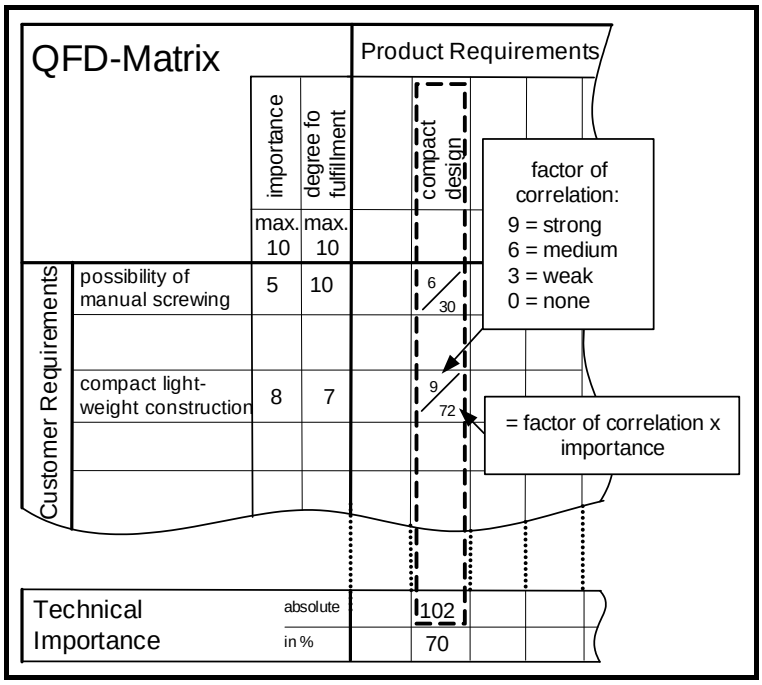

Figure 3. Section of QFD – House of Quality

Based on this first QFD phase, the evaluation method was enhanced by the following solution steps:

Solution Step 1:

Product survey by means of the QFD method to obtain important parameters from the customer and product requirements for the evaluation algorithm.

The results from the first QFD phase, the "technical importance of the product requirements" are the key variables for the evaluation algorithm. They represent important aspects such as weighting and fulfilment of the customer requirements as well as the realisability of the product requirements.

Solution Step 2:

Modification of the QFD matrix to record the importance of the novelty of the product.

The question concerning the importance of the novelty of an innovation entails the analysis of customer and product requirements in the context of the central parameter *novelty.* The meaning of the expression *"importance of novelty"* can be seen from the answer to the following question: To what extent can the product be judged as *new* in comparison to already existing products, if both customer and product requirements are fulfilled?

Solution Step 3:

Analysis and recording of influencing variables for each product requirement by modifying the QFD matrix.

The product requirements must be technically implemented. The means and possibilities used depend to a great extent on the competence of an innovating enterprise. Favourable influ-

ences on the product manufacturing lead to *product success* in the market and *enhanced manufacturer benefit.* Therefore, for each product requirement, influencing variables regarding product success must be analysed and taken into consideration.

Solution Step 4:

Creation of an evaluation algorithm to determine the success potential and the degree of innovation.

The objective of this method is the determination of quantitative parameters to allow a statement about the chances of market penetration (success potential) and the degree of novelty of technical ideas and products. Based on the *technical importance of the product requirements*, the *importance of novelty* and the *influencing variables on product success*, a mathematical evaluation algorithm must be established to quantitatively determine the success potential and the degree of innovation.

These solution steps are the basis for the new evaluation method which is described in the following.

5 Evaluation method

5.1 QFD product survey

5.1.1 Input of product parameters

The first phase of the QFD method (see Figure 3) is, in a modified form, the origin for the appraisal and evaluation method. In order to allow the quantitative rating of the central parameter of an innovation, the *novelty of the product*, the column “novelty importance of the customer requirements” and the row “novelty importance of the product requirements” must be integrated into the evaluation matrix. The size of the numerical values to be entered depends on the degree of novelty or the importance of the novelty of each requirement with regard to incremental or radical innovations in natural science and engineering (Figure 4).

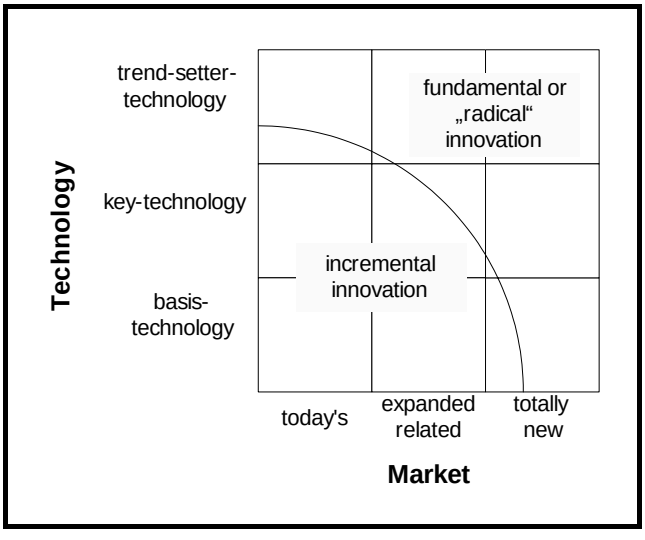

Figure 4. Incremental and radical innovations [13]

The procedure for drawing up the evaluation matrix is divided into the following steps:

1. The customer requirements are entered vertically, the product requirements are entered horizontally. In the case of extensive product specifications, a classification according to main headings is useful.
2. The customer requirements are weighted according to their importance.
3. Determination of the importance of novelty of the customer and product requirements by using a scale from 0 to 10 points. If, e. g. for the product requirement no. 1 in Figure 5 “high gear ratio”, the value 6 is entered for the importance of novelty, then the “share of novelty” in the product requirement is estimated to be 6/10 or 60 %.
4. Determination of the degree of fulfilment of the customer requirements by quantitative identification of the values in comparison to competitive products (bench marking).
5. Correlation between customer and product requirements.

   Here, the strength of the correlation determined by the correlation factors is particularly relevant. Later, special attention must be paid to customer requirements with high weighting factors and strong correlations to several product requirements.

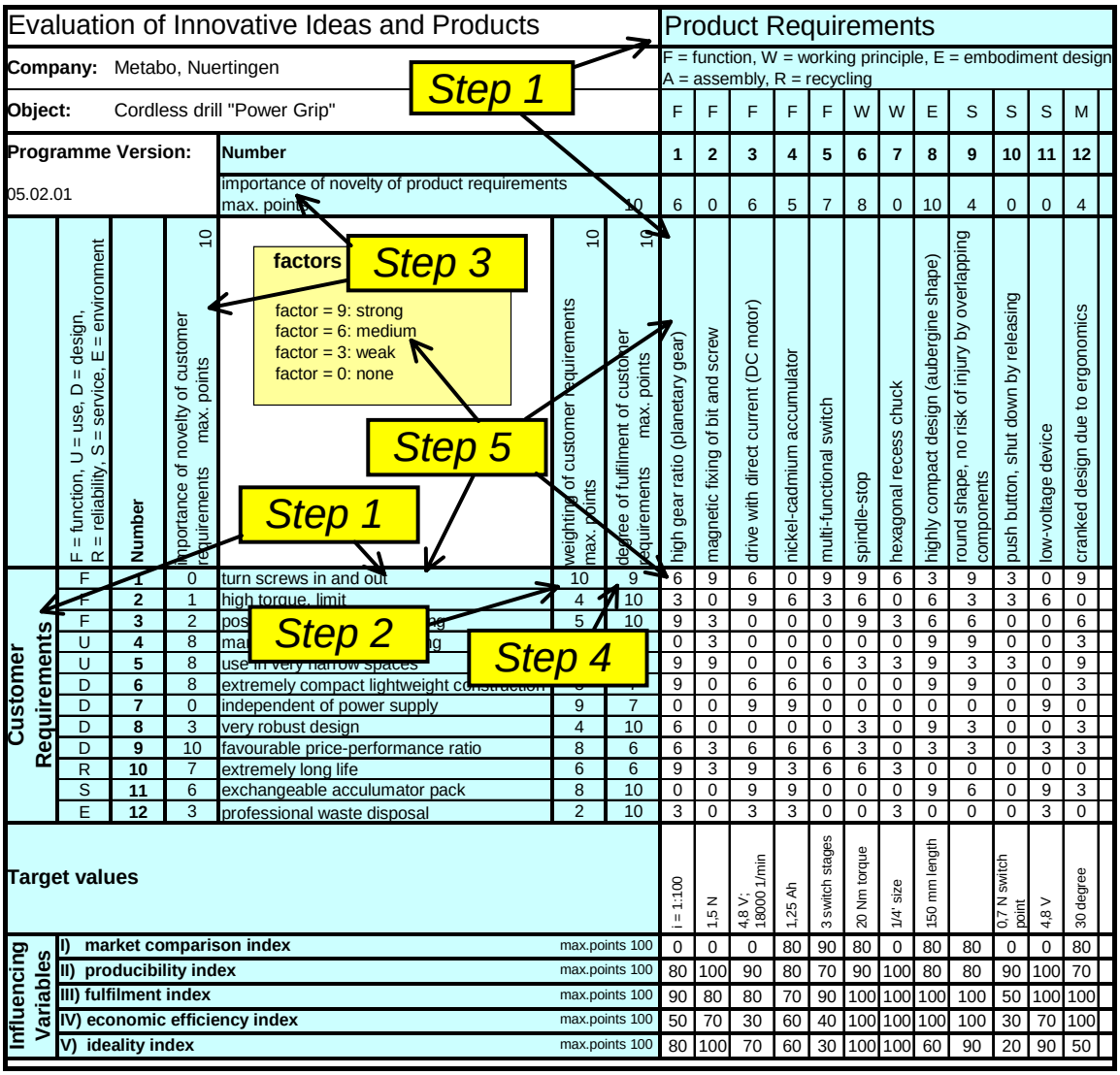

Figure 5. Procedure to fill in the evaluation matrix

5.1.2 Calculation of technical importance

The technical importance of a product feature according to the QFD method is the key variable for an evaluation because it includes the important aspects “customer orientation and technical feasibility”.

The technical importance is determined according to the following steps (Figure 6):

6. For all product requirements, the correlation factor is multiplied by the weighting factor of the customer requirements.
7. Addition of all these (mathematical) products within a product requirement. This is carried out for all product requirements.
8. In a further step, it is advisable to calibrate the calculated values by use of a scale from 0 to 100. In the example shown, the maximum technical importance 423 (product requirement no. 6, Figure 8) corresponds to 100. The technical importance of the first product requirement is 375, corresponding to 89.

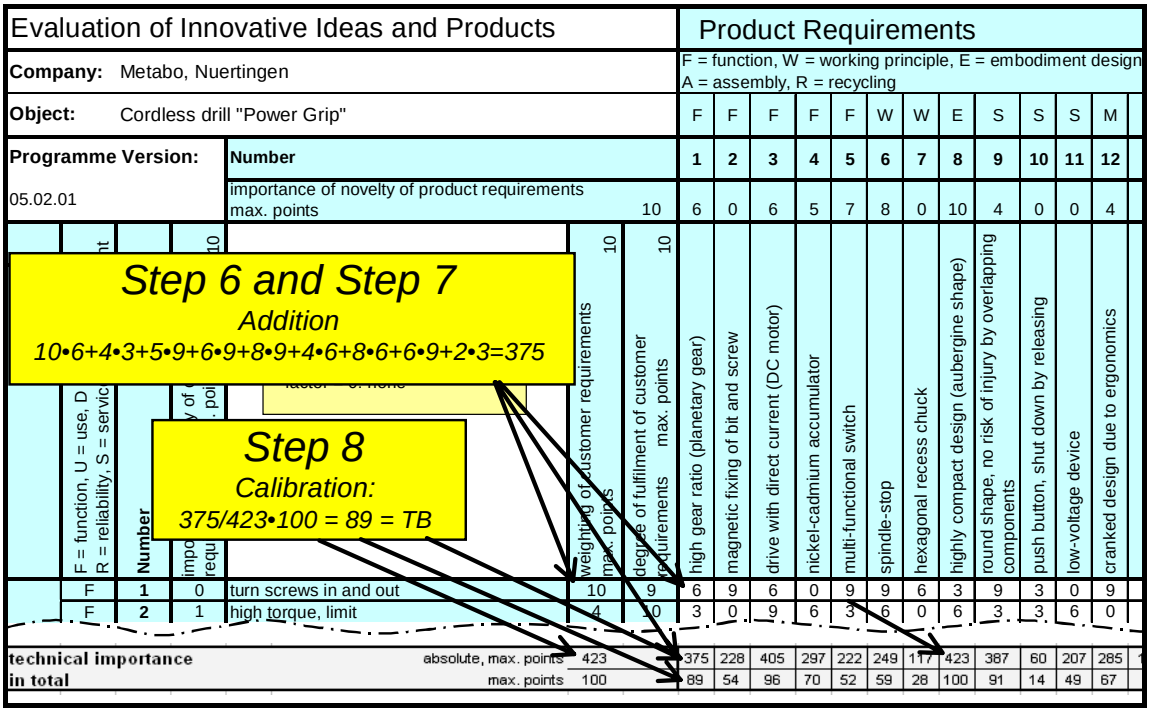

Figure 6. Determination of technical importance

5.2 Influencing variables on product success

The evaluation matrix is extended by the influencing variables on product success (Figure 5). They are necessary for a comprehensive evaluation with regard to the *enhanced manufacturer benefit* of an innovation. The individual influencing variables range from 0 to 100. High values represent a positive effect on the product success.

Comments on the influencing variables on product success:

I) Market comparison index:

The data to be entered must be assessed by comparing the objectives of the product under analysis with the objectives of the competitive products since realistic data can

only be obtained by permanent long-term market observation. High values must be entered if the product has a high performance.

II) Producibility index:

This assessment requires the knowledge of experts. A high value represents a low manufacturing risk. In general, the risk of failure depends on increasing manufacturing difficulties. Fewer product requirements in difficult manufacturing fields result in a higher stage of manufacturing maturity of a product. This means a lower risk of failure.

III) Fulfilment index:

These values refer to the reliability and the probability of fulfilment of the product requirements. In case of a high risk of non-fulfilment or a high sensitivity to negative influences, the risks should be determined and minimised by taking the necessary measures to increase the "stage of maturation" of the product.

IV) Economic efficiency index:

As far as the economic efficiency aspects are concerned, costs, complexity of manufacturing and assembly, investment costs, etc. must be moderate to ensure economic success. Therefore, these economic efficiency aspects must be taken into consideration during the development phase of the product. The costs can be determined by approximation procedures, e. g. by comparison or similarity observations, estimation of proportional costs of material, etc.

V) Ideality index:

This index includes the need for additional functions to achieve the objective. If one or more "additional functions" are necessary to achieve a certain function or purpose, additional resources are required. Therefore, a solution with a high "degree of ideality" is also a solution with low destructive side effects [5]. In most cases, a customer prefers products with a high degree of ideality.

This list can be supplemented according to the object to be investigated without changing the basic evaluation algorithm.

5.3 Calculation of the success potential and the degree of innovation

In order to determine the success potential and the degree of innovation, indicators must be identified by a mathematic link between the key variables from the QFD product assessment, the *technical importance* of the product requirements and the *influencing variables on product success*. These indicators should reflect the degree of fulfilment of the customer requirements and the feasibility of the product requirements including all prerequisites and risks.

5.3.1 Calculation of the valuation factors

The determination of individual indicators is based on mathematic links between the technical importance and the influencing variables I to V. The links are represented in five portfolios. For example, Figure 7 shows the portfolio of the influencing variable “producibility index”.

Modus operandi:

1. For each product requirement, the value of the influencing variable is plotted versus the technical importance in the respective portfolio. Example: The product requirement no. 1 has a relative technical importance of 89 (see Figure 6) and a producibility index of 80 (Figure 5).
2. By means of mathematic averaging, an individual valuation factor ($E_{I,i}$ … $E_{V,i}$) is assigned to the numbers pairs. Therefore, in the above mentioned example, the individual valuation factor is

$$E_{II,i} = (89 + 80)/2 = 84{,}5.$$

3. A total valuation factor (E_I … E_V) is calculated by arithmetical averaging of all individual valuation factors of one portfolio.

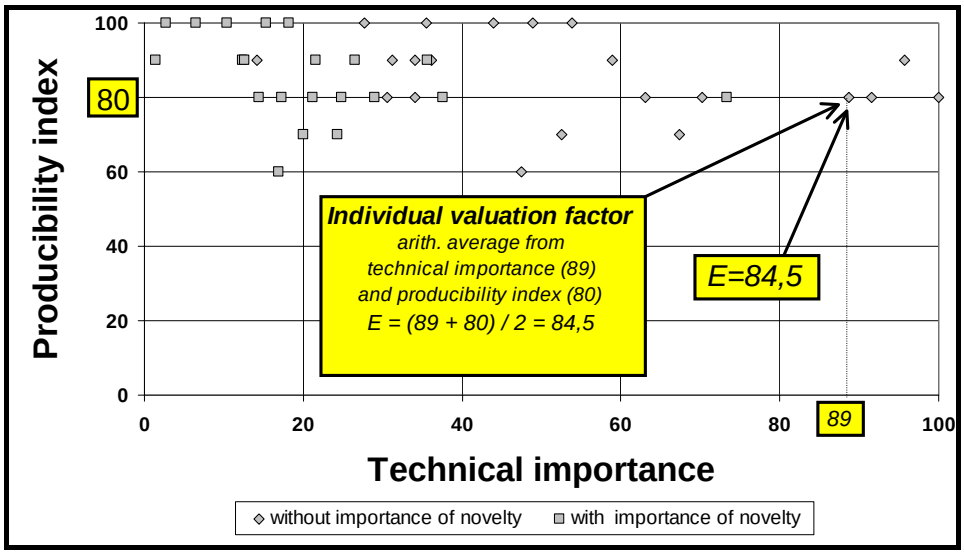

Figure 7. Portfolio: Producibility index versus technical importance

The points in the upper right-hand area of the portfolio (Figure 7) are of special importance. If, for example, a high technical importance is given to a certain product requirement and if the influencing variable “producibility” is high as well (i. e. easy to produce), this results in a high individual valuation factor that means a favourable influence on the product success from a technical point of view. The obtained influence valuation factors (E_I … E_V) are the important indicators for the following calculation of the success potential.

5.3.2 Calculation of success potential

The average value is then calculated from the five valuation factors (E_I … E_V) resulting from the mathematical links of the technical importance and the influencing variables I to V. Because of the above-mentioned definition, an evaluated object with a high average value will most probably be successful on the market. This average value calculated from the influenc-

ing variables is identified as *success potential*. This specification now allows the definition of the term "success potential" on a mathematical basis:

The success potential of an innovative idea or product results from the average value of the valuation factors of the influencing variables on product success.

In other words, the calculated amount of the success potential allows a prognosis to be made of the chances of the object under evaluation in terms of its potential market penetration.

The success potential is calculated as follows:

Averaging of the (in some cases weighted) valuation factors of the influencing variables.

$$E_P = (p_I \cdot E_I + p_{II} \cdot E_{II} + p_{III} \cdot E_{III} + p_{IV} \cdot E_{IV} + p_V \cdot E_V)/(p_I + p_{II} + p_{III} + p_{IV} + p_V) \quad (1)$$

E_P: Success potential

$p_I \ldots p_V$: Weighting factors

$E_I \ldots E_V$: Valuation factors of the influencing variables I to V

5.3.3 Calculation of the maximum value of the success potential

The calculation of the theoretically possible maximum value of the success potential is based on the maximum possible values of the individual influencing variables. The ratio of the calculated success potential to this maximum value characterises the capability of the test object, even if no comparable objects such as competitive products are available. In some cases it is sufficient to know in which range a potential is placed, i.e. in an upper, medium or lower range.

5.3.4 Calculation of the degree of innovation

The central parameter of an innovation is the importance of novelty of the product which has been determined by an estimated value of the importance of novelty for each customer and product requirement. The described calculation for one individual product requirement must be carried out for all customer and product requirements. By means of these numerical values it is now possible to determine the "share of novelty" in each technical importance of the product requirement (Figure 8). The determined "shares of novelty" of the technical importance are the basis for continuing the calculation of the degree of innovation.

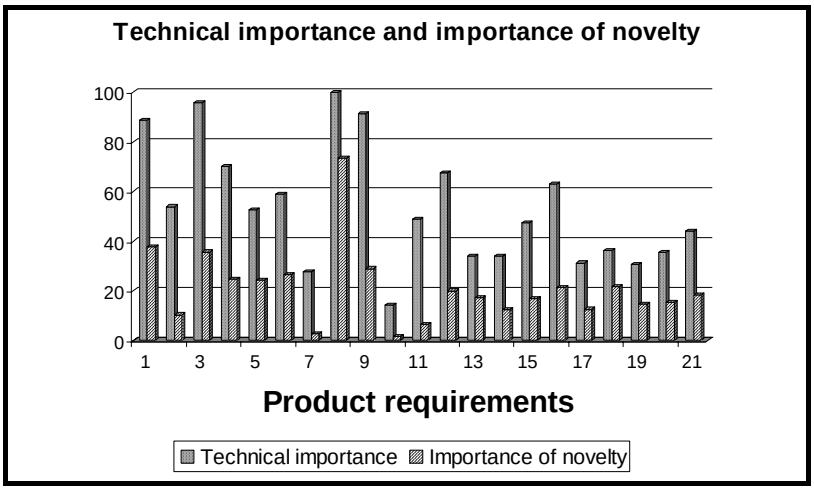

Figure 8: Technical importance and importance of novelty of the product requirements

The following calculation is done in the same way as the calculation of the individual valuation factors. The technical importance – now only the shares of novelty – and the influencing variables I to V are also displayed in two-dimensional portfolios, the individual valuation factors are calculated and the influence valuation factors are determined out of this.

The method of calculation is quasi the same as for the calculation of the success potential. As now only the "share of novelty" of the technical importance is used for calculation, the result obtained is the "share of novelty" of the success potential. This can also be called "novelty potential" or, even better, "degree of innovation", since all innovative parameters are taken into consideration in this calculation:

The degree of innovation of an innovative idea or a product is the share of novelty in the success potential.

The degree of innovation is then calculated as follows:

Averaging of the (in some cases weighted) valuation factors of the influencing variables taking the novelty into account.

$$I_G = (q_I \cdot I_I + q_{II} \cdot I_{II} + q_{III} \cdot I_{III} + q_{IV} \cdot I_{IV} + q_V \cdot I_V)/(q_I + q_{II} + q_{III} + q_{IV} + q_V) \quad (2)$$

I_G: Degree of innovation

$q_I \ldots q_V$: Weighting factors

$I_I \ldots I_V$: Valuation factors of the influencing variables I to V *with novelty*

The recapitulating flow process chart in Figure 9 shows the steps of the new evaluation method. The symbolism of the arrow in the procedure expresses that initially the success potential is calculated (complete arrow) and then, under consideration of the share of novelty (hatched part of arrow), the degree of innovation is determined.

6 Validation of the evaluation method

The evaluation algorithm was tested and validated in pilot projects. On the one hand, this was carried out with products already on the market and, on the other hand, with innovative product ideas from the development and design phase. The pilot projects selected were typical projects of the consumer and the investment goods industry. The completed evaluations should show a spectrum of possible results in the innovation process.

Table 1. Results of pilot projects

Project	Unit	Company	Success potential	Degree of innovation
A	Cordless drill "Power Grip"	Metabo, Nürtingen	81,9 %	56,2 %
B	Snowblower	X	75,0 %	39,5 %
C	Modular multiphase low-cost electric drive	Y	81,0 %	58,1 %
D	Miniature translation stage	Festo, Esslingen	83,0 %	56,0 %

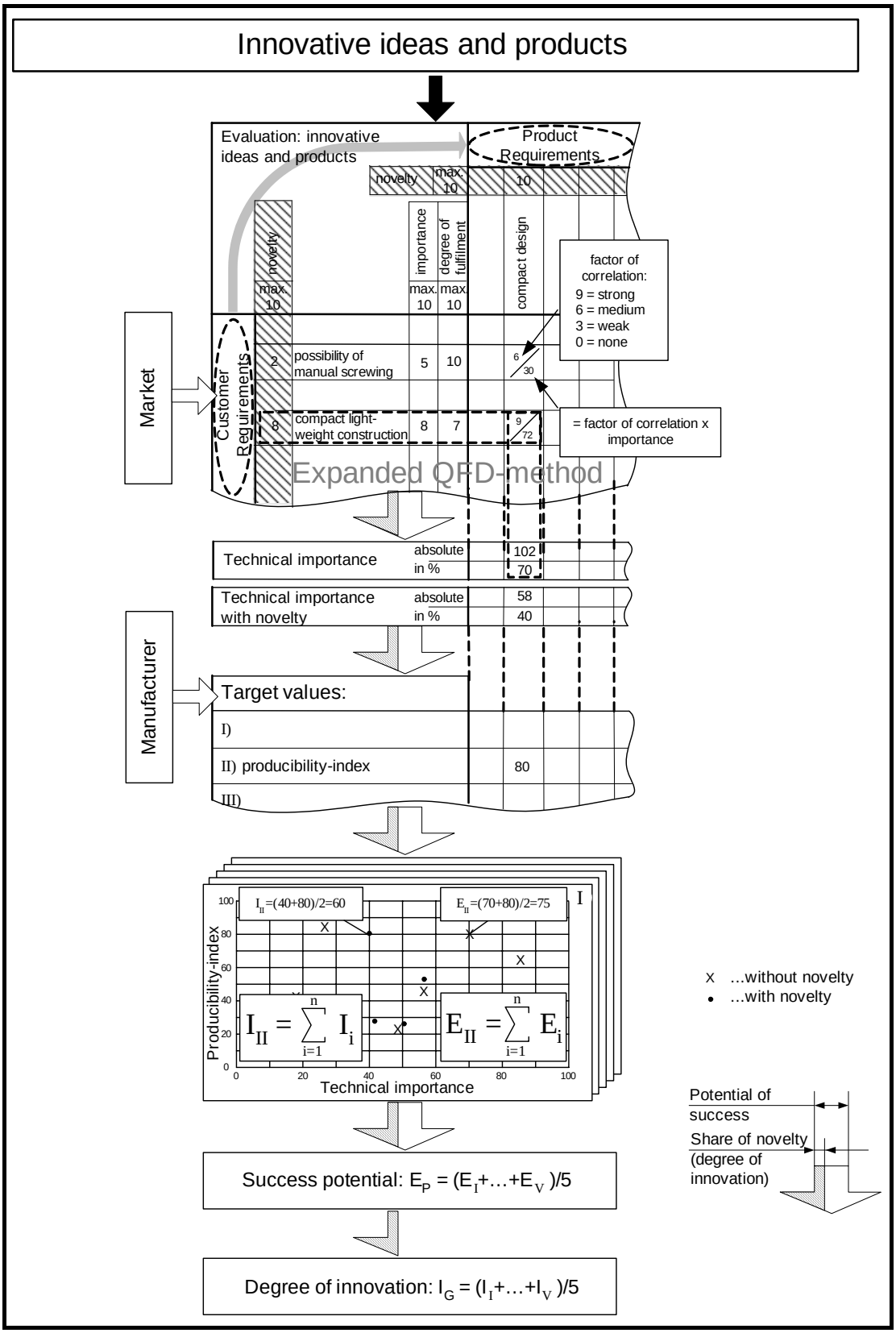

Figure 9. Evaluation algorithm for innovative ideas and products

As an important result of the pilot project stage the following statements can be made. At the beginning of an evaluation, the object to be evaluated is often wrongly rated, i. e. the "importance" of success and innovation is overestimated. On a closer examination and analysis,

many innovations are “simply” a new combination of already existing solutions. Only very seldom is a “new, revolutionary idea or solution” created. Therefore, mostly smaller numerical values, as expected from the previous qualitative and often general appraisals, result from this relatively accurate and sophisticated new evaluation method.

7 Conclusion

A basic result of the pilot projects examined is that the evaluation is possible at an early stage of the innovation process, from the moment that concrete customer requirements are known. Here “customer” does not only mean the “external” customers of the free market who are interested in a certain product, but also the “internal” customers, i. e. the members of staff of a department of the same company who place an order with a research and development department.

The following results arose from discussions with the companies involved about the applied procedures and the conclusions drawn from the evaluation data.

1. It is possible to evaluate
    a) individual segments of the innovation process of a product (starting with the customer specifications)
    b) technical subsystems during the development phase
    c) products on the market.
2. The evaluation results are particularly qualified as a decision-making aid in product development. Important planning data obtained from the customer management and the technical feasibility of the product requirements, i. e. aspects of the enhanced customer and manufacturer benefit, are taken into account.
3. Ideas and products mostly arise from a combination of conventional design elements and/or partial solutions for a new purpose. Real major novelties are seldom. Many evaluation results often range between medium and lower levels.
4. The evaluation method supports an overall entrepreneurial evaluation and gives important advice to the management with a view to improving an enterprise’s innovation capability.

That the objective as far as development of a new evaluation method is concerned has been achieved is evidenced by the results obtained during the pilot project stage. For the first time, it is now possible to quantitatively determine parameters to evaluate the potential for market penetration and the degree of novelty of innovative ideas or products in comparison with competitive products.

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